

EFFECT OF SALINITY ON GROWTH OF POSTLARVAL PENAEID SHRIMP¹

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The general life-history pattern of commercially important penaeid shrimps of the northern Gulf of Mexico has been known for some years (Pearson, 1939; Weymouth, Lindner and Anderson, 1933; Burkenroad, 1939). That the adults spawn offshore, the young migrate shoreward to the estuaries for a period of rapid growth, and then return to the offshore areas is generally accepted. However, neither the stimulus for the migrations nor the factors controlling the period of time spent in the estuaries are well understood. Several explanations for this behavior have been advanced. Some authors indicate that salinity *per se* is of prime importance. For example, Pearse and Gunter (1957) state (p. 147): "The young of many animals, usually thought of as marine, require areas of low salinity for nursery grounds. The distribution and abundance of the blue crab and the commercial shrimp (*Penaeus setiferus*) on the South Atlantic and Gulf coasts are dependent on the presence of estuarine areas. The shrimp spawn in oceanic salinities; the early stages apparently require oceanic water, but the older larvae must reach bay waters or perish. The young shrimp grow up in the low-salinity bays and return to the sea." Other authors, including Lindner and Anderson (1956) and Hoese (1960), have felt salinity to be of less importance. Broad (1962, p. 1), referring to penaeids, remarks: "Thus, while almost every investigator during the last thirty years has considered salinity in relation to shrimp distribution . . . it is still not possible to state what effect salinity may have, for example, on the growth of shrimps." The following experiments were designed to evaluate the effects of salinity upon the growth of postlarvae of the white shrimp, *Penaeus setiferus*, and either the brown shrimp, *P. aztecus*, or the pink shrimp, *P. duorarum*.

MATERIALS AND METHODS

Two series of growth experiments were conducted, the methods being generally the same in each. Large numbers of postlarval shrimp were seined from nearby surf zones for use as experimental material in both series. Prior to transfer into experimental vessels, the small shrimp were held for 24 hours under laboratory conditions in quantities of the same water in which they were caught, or in water of the same salinity. One hundred postlarval penaeids were placed in each experimental tank; the salinity of the medium at this time was identical to that at which the animals had been caught. Salinity was decreased stepwise by removing sea water and replacing it with an equal volume of distilled water. Salinity was increased

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similarly using concentrated sea water in place of distilled water. Stepwise salinity changes required 48 hours in the first series (GS-1) and 120 hours in the second (GS-2) (Table I).

The experimental vessels consisted of 20-gallon glass aquaria fitted with "Eureka" inside plastic filters which filtered and aerated the water. The filters were covered with ground oyster shell topped with fine beach sand, the combination serving both as a filter bed and as a substrate for the animals. Both shell and sand were washed and heat-sterilized before use. At the start, 40 l. of sea water were added to each aquarium. The initial salinity of the water was 25‰ (parts per thousand) in series GS-1 and 39‰ in series GS-2. Salinity was determined semi-weekly using a hydrometer.

A thin (2-mil) polyethylene film was placed in contact with the surface of the water in the experimental tanks to reduce evaporation and to prevent escape of

TABLE I
Schedule of salinity changes

Date	Elapsed time (hr.)	Initial salinity (‰)	Desired salinity				
			2‰	5‰	10‰	25‰	40‰
Series GS-1:							
4/12/62	2	25	—	20	20	No change	33
	7		—	15	15	No change	38
4/13/62	26		—	10	10	No change	40
	31		—	5	10	No change	40
Series GS-2:							
7/26/62	3	39	35	35	35	35	40
	8		30	30	30	30	40
7/27/62	24		25	25	25	25	40
	31		21	21	21		
7/28/62	48		17	17	17		
	55		13	13	13		
7/29/62	72		10	10	10		
	63		7.5	7.5			
7/30/62	96		5.0	5.0			
	104		2.0				

the postlarvae. During preliminary work in the absence of the film, as many as 20 postlarvae had been found trapped on the side of a tank in a single day. That this method was successful in reducing such losses is indicated by the 100% survival noted in some sections of the experimental series.

The schedule of salinity changes in the two series is given in Table I. Salinity reduction required more time during the second series because of the higher initial salinity. In neither series were deaths noted during the acclimation period.

During both series of experiments the laboratory temperature was maintained at 23 to 25° C. while the water temperature ranged from 24.5 to 26° C. Each aquarium was continuously illuminated by two 14-watt daylight fluorescent bulbs.

It should be noted that the animals in the two series were caught at different water temperatures. Animals in series GS-1 came from water of 23° C. whereas those in GS-2 came from water of 30° C.

Initial measurements in each experiment were obtained from samples of 10 postlarval shrimp withdrawn from the source population. After excess water was removed, the length of each specimen was measured to the nearest 0.5 mm. (distance from tip of rostrum to end of telson), and its weight determined to the nearest 0.1 mg. on a Mettler H15 analytical balance. All individuals were preserved for later study. Subsequent samples from each experimental tank were similarly treated after being withdrawn at approximately 5-day intervals. Both the largest and the smallest specimens in each tank at each sampling period were

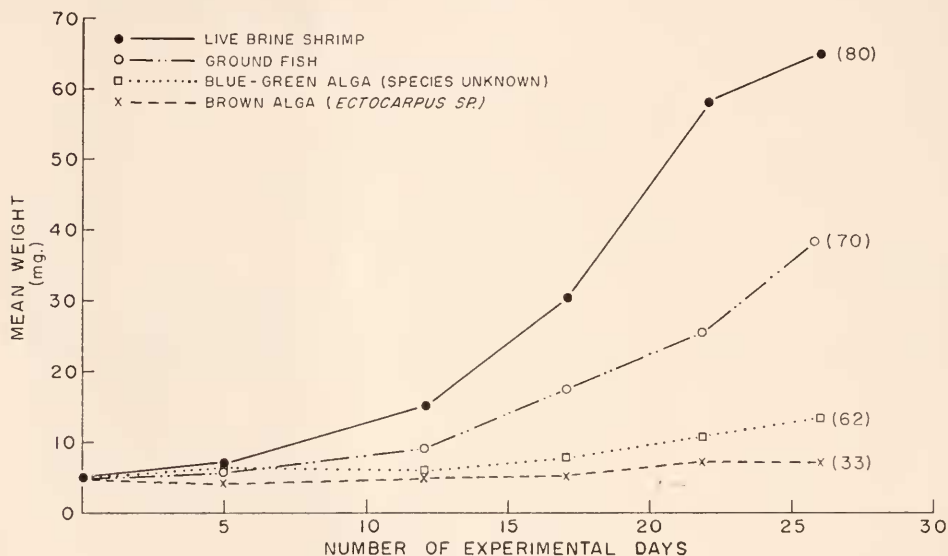


FIGURE 1. Growth of postlarval penaeids fed various diets. Figures in parentheses indicate percent survival at termination of experiment.

included in order to determine size ranges; the remaining eight were selected at random. After approximately 30 days, the surviving animals in each tank were weighed individually and preserved.

Preliminary experiments which were of similar design and carried out at 25‰ had indicated that a live food was to be preferred. Figure 1 not only indicates that growth was substantially better among the postlarvae fed brine shrimp, *Artemia*, nauplii, but that survival was also greater. As Williams (1959) has previously noted in the brown shrimp, those animals fed algae always had full guts and deposited deep green or brown feces, but neither their growth nor their survival approached the levels attained by animals fed the brine shrimp diet. In addition to a slightly poorer growth rate among animals fed ground fish or shrimp, there was a practical problem caused by fouling of the water with excess food. For

these reasons, brine shrimp nauplii constituted the sole dietary supply in the salinity experiments described. Laboratory cultures of brine shrimp were filtered and washed before use in order to avoid salinity changes in the experimental tanks caused by the addition of saline (brine shrimp) culture medium. Equal amounts of brine shrimp were given to postlarvae in all tanks. The volume and number of feedings per day were increased during the experiment in order to maintain an excess of food in the tanks.

Although all the shrimp in series GS-1 (April, 1962) were tentatively identified as grooved shrimp, *i.e.*, brown shrimp or pink shrimp, those obtained for GS-2 (July, 1962) apparently included both "grooved" and white shrimp in an approximate ratio of five grooved to one white. Tentative species identification was made following Williams (1959), with early postlarvae (less than 10 mm. rostrum-telson length) being differentiated on the basis of ratio of distance from rostrum to eye and distance from third pereopod to eye, and specimens longer than 17 mm. on the basis of the presence or absence of a groove. Conflicting evidence is available concerning identification at lengths between 10 and 17 mm. Thus, identification must be regarded as tentative, although some confirmation of species ratio was available from the animals surviving for 30 days.

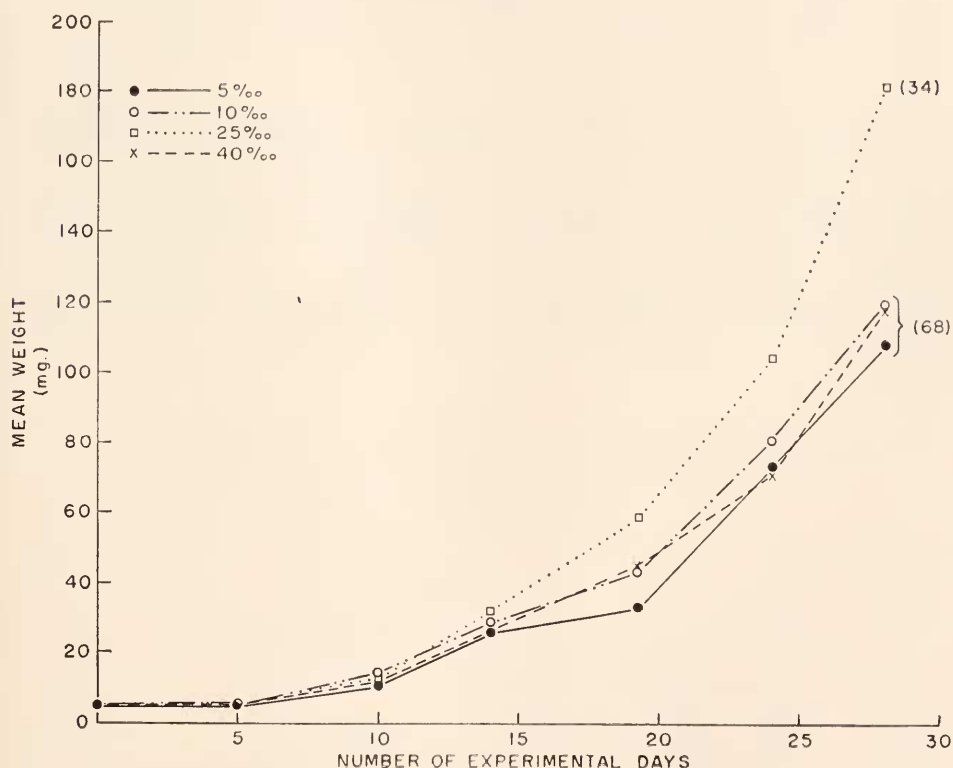


FIGURE 2. Growth of postlarval penaeids at various salinity levels in series GS-1. Figures in parentheses indicate percent survival at termination of experiment.

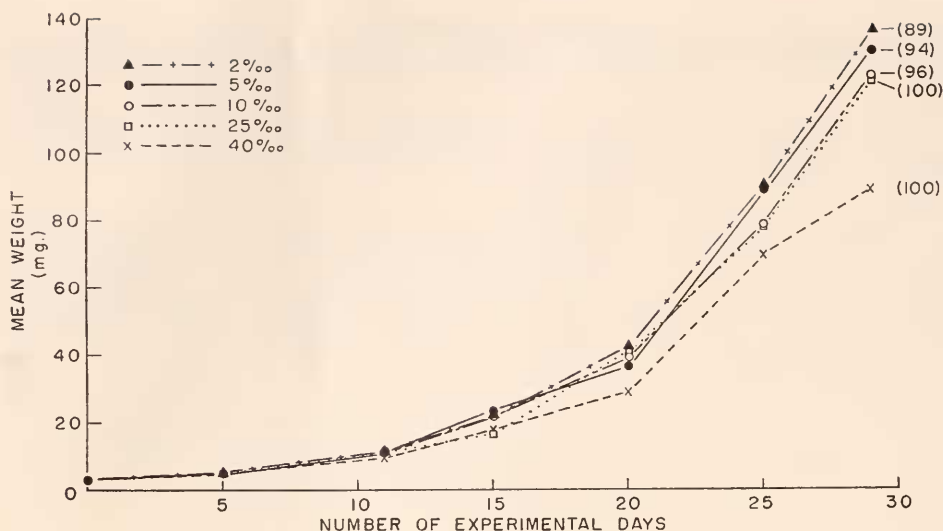


FIGURE 3. Growth of postlarval penaeids at various salinity levels in series GS-2. Figures in parentheses indicate percent survival at termination of experiment.

As indicated in Figures 2 and 3, growth of the postlarvae occurred at all salinity levels tested in both series of experiments. Growth has been expressed as total weight in mg. (Tables II and III) rather than as total length since, as shown in Figure 4 (which is based on animals measured during these experiments), weight increases more rapidly than length and is therefore less influenced by relative measurement error. Thus, in the first 5 days, weight increased by about 50% while total length increased only 15%. In each subsequent 5-day period weight generally doubled while length was increasing only 25%. For this reason weight has been used here as a more sensitive indicator of growth than total length.

TABLE II

Mean animal weight (in mg.) at each salinity level in experimental series GS-1. Values are based on weights of 10 animals. Figures in parentheses indicate one standard error

Elapsed days	Salinity level			
	5‰	10‰	25‰	40‰
0	—	—	4.5 (0.2)	—
5	5.7 (0.3)	5.4 (0.6)	6.6 (0.4)	6.2 (0.4)
10	14.1 (1.4)	10.9 (0.9)	13.0 (1.5)	11.9 (0.8)
14	29.1 (3.3)	26.2 (3.6)	32.6 (4.4)	26.3 (4.2)
19	43.8 (5.0)	32.7 (6.0)	58.9 (10.6)	45.4 (10.4)
24	81.4 (9.2)	72.9 (8.6)	104.7 (14.2)	71.3 (6.8)
28	119.6 (13.6)	108.7 (18.6)	182.0 (18.8)	118.0 (19.1)

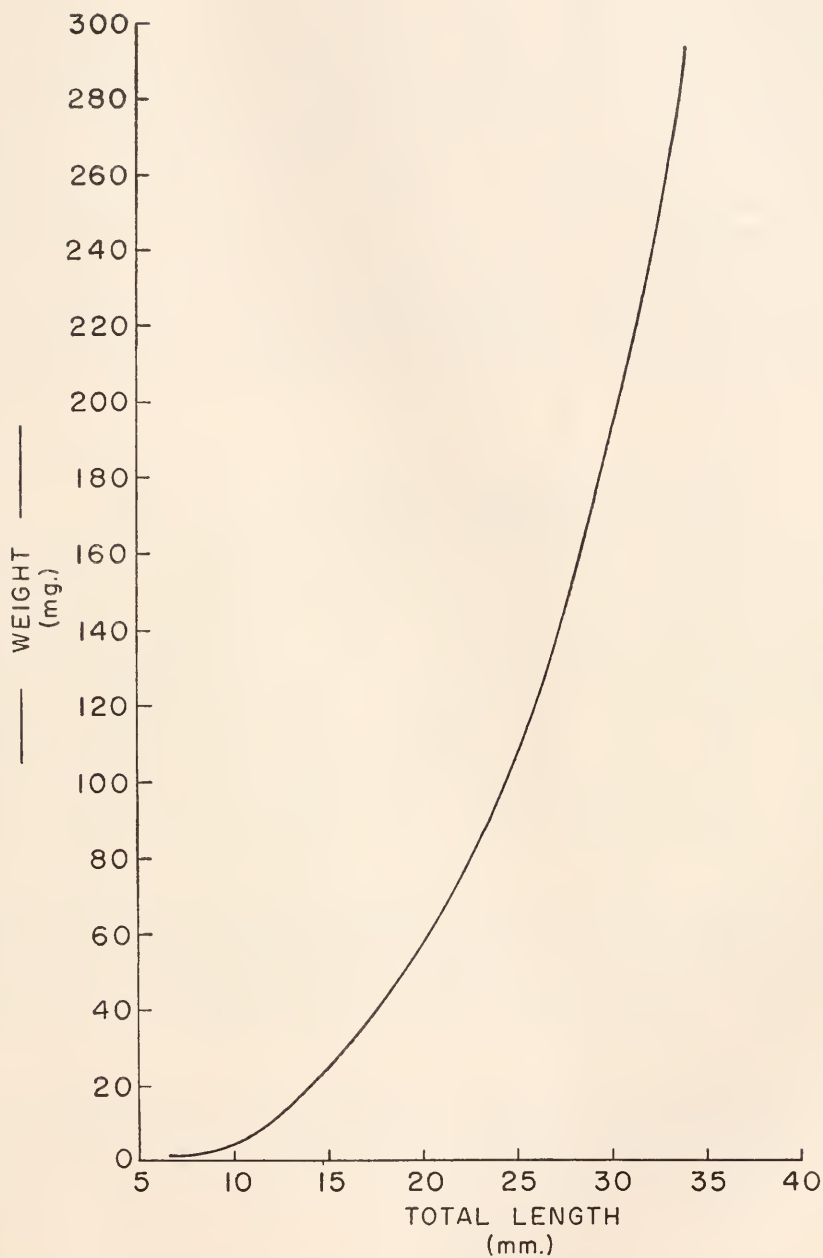


FIGURE 4. Weight-length relationship in postlarval penaeids.

Although growth appeared to be much greater in the first series at the 25‰ salinity level, it must be noted that the per cent survival was considerably less than that at the other salinities (Fig. 2). Comparison by *t* tests of mean weight increments at 25‰ *vs.* those at other salinity levels revealed that growth at the former level was greater throughout the series than at any other level tested. The increased growth rate may be related to the fact that more food was available for each surviving animal as a result of the increased mortality, or it may be a simple reflection of the decreased population density. There was no apparent reason for the greater mortality in this tank, and, indeed, as noted in earlier feeding experiments (all conducted at 25‰) as well as in the later salinity series GS-2, both growth and survival were rated as excellent at this salinity. No significant difference between other pairs of means in this series could be detected.

In the second series of experiments (GS-2), survival was considerably better than that occurring during the first series. All test animals survived at both 40‰ and at 25‰, and survival in no case was less than 84%. This better survival may

TABLE III

Mean animal weight (in mg.) at each salinity level in experimental series GS-2.
Values are based on weights of 10 animals. Figures in parentheses
indicate one standard error

Elapsed days	Salinity level				
	2‰	5‰	10‰	25‰	40‰
0	—	—	—	2.9 (0.2)	—
5	4.8 (0.2)	4.8 (0.2)	4.3 (0.1)	4.3 (0.4)	4.3 (0.4)
11	11.1 (1.6)	10.8 (1.2)	11.0 (1.0)	9.9 (1.2)	9.9 (1.2)
15	21.2 (2.7)	23.1 (4.0)	22.6 (3.5)	16.5 (2.0)	17.8 (2.9)
20	42.6 (7.3)	36.5 (9.0)	36.9 (6.3)	40.3 (7.1)	19.1 (2.3)
25	90.2 (21.2)	88.9 (24.4)	78.6 (17.0)	77.3 (12.2)	69.6 (10.6)
29	140.9 (23.3)	147.4 (27.7)	135.0 (31.2)	138.4 (22.2)	94.7 (10.4)

have been due to a difference in the medium (sea water for GS-2 was obtained directly from the surf zone whereas that for GS-1 came from a large recirculating sea-water system), or to better feeding. It is significant that 100% survival occurred in the two highest salinity levels and that considerable growth occurred even at 40‰. This would indicate that postlarval penaeids are not only able to withstand such high salinity for a fairly long period of time, but can grow at a rate nearly as great as that attained at presumably more "normal" levels.

It is interesting to note that the rate of growth varied considerably among individuals within the same tank, regardless of the salinity. Specimens in initial samples ranged from 3.6 to 5.6 mg. and from 10.0 to 11.0 mm. in GS-1, whereas animals in GS-2 ranged from 1.3 to 3.8 mg. and from 6.5 to 10.0 mm. However, at 29 days, when experiment GS-2 (25‰) terminated, weights varied between 39.5 and 305.4 mg. and lengths between 17.0 and 36.5 mm. Such variation was noted during both series of experiments. In each, growth exceeded that recorded by Pearson (1939) for either white or "brown" shrimp postlarvae in laboratory aquaria, but was probably less than that occurring under natural conditions.

DISCUSSION

Although salinity has long been considered a major factor in the ecology of commercial penaeid shrimps, few data have been available either to substantiate or negate claims that low salinity is a requirement for the growth of postlarval shrimp. That postlarval shrimp are found in low salinity water is an undisputed fact, but the influence of salinity *per se* on this distribution has not been determined. Lindner and Anderson (1956) reported that the size of young shrimp was correlated more with locality than salinity and concluded that salinity within broad ranges was not important. Hoese (1960) states (p. 593): "It would seem that within certain areas, at least, salinity in broad ranges is inconsequential to young shrimp. All the habitats where juveniles have been found could offer protection from predators. . . . It appears that juvenile *P. setiferus* and *P. aztecus* can populate areas of relatively high salinity if other environmental factors are ideal." Gunter, too, has modified his stand concerning the importance of salinity. He states (1961, p. 599): "Small shrimp are not killed or precluded by high salinity as if it were poison; they simply do not do well in it, for reasons unknown." Nevertheless, he mentions finding 115 white shrimp ranging in length from 15–66 mm. in the Laguna Madre at a salinity of 41.3‰. Johnson and Fielding (1956), in attempts to rear shrimp in ponds, noted that white shrimp could be raised at salinity levels of 18.5 and 34‰, and Williams (1960), in experiments concerning the osmotic relationships of brown and pink shrimp, found that temperature apparently had far more effect upon survival than did salinity. The experiments presented here indicate that under the conditions tested (restricted temperature and diet), postlarval shrimp can both survive and grow over a wide range of salinities. Thus, it would appear that salinity tolerances *per se* may not play a direct role in the growth and survival of postlarval and juvenile shrimp in the estuarine environment.

It may be tentatively suggested that food requirements may be of more importance than the purely physical factors. Some indication of this food requirement was noted during these experiments, for it was, in fact, the inability to provide food in sufficient quantity which terminated the experiments after only a month. The relationship of growth to utilization of food is now being studied in an effort to obtain an estimate of the food required to produce a given weight of shrimp. Further studies will test the effect of population density upon growth. Future work will also include experiments concerning the interrelation of temperature and salinity and their combined effect upon the growth of postlarval shrimp.

The method of preventing postlarval escape by use of polyethylene film was designed by Dr. David V. Aldrich. His help and the assistance of Mr. Don S. Godwin and Mr. Roger M. Friedberg is gratefully acknowledged.

SUMMARY

1. The effect of salinity on the growth and survival of postlarvae of white, *Penaeus setiferus*, and grooved shrimp, *P. aztecus* or *P. duorarum*, has been studied in the laboratory.

2. Growth rate did not differ significantly among shrimp held at 2, 5, 10, 25, or 40‰.
3. Survival was generally excellent at all salinity levels tested, including 40‰.
4. The results suggest that salinity *per se* does not limit growth of young shrimp.

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